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54 IR scanning device for producing a stereoscopic image.

57 A stereoscopic infrared imager includes optics (18, 20, 26, 22) for producing infrared images of two different views of an infrared scene. A scanning mirror (26) alternately scans the two infrared images across a single infrared detector array (24). The detector array modulates a light source array (28) to produce a visible image of the scanned part of the infrared scene. Optics (32, 38, 34, 36, 52, 54) are provided for producing visible images of the light source array at the positions of the eyes (40) of the observer. A second scanning mirror (38) alternately scans the image of the light source array across the two eyes of the observer in order to construct full visible images of the scene.

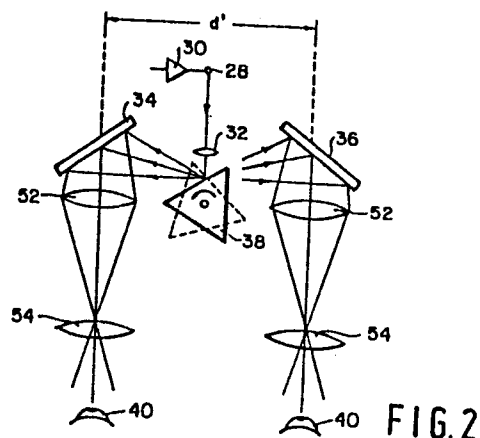
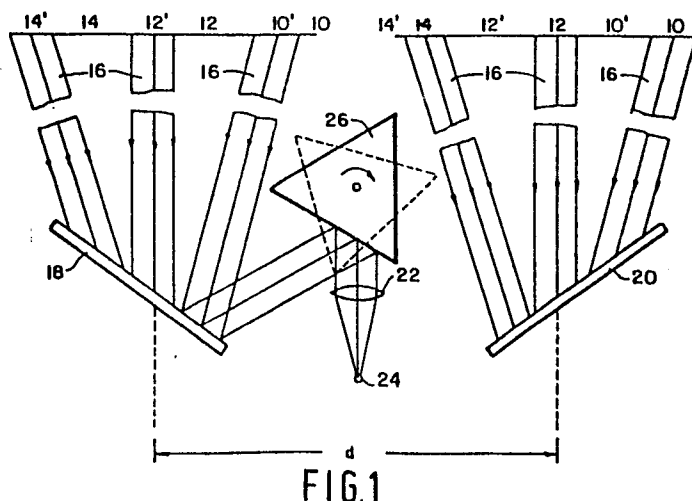


FIG. 2

Device for producing a stereoscopic image.

The invention relates to a device for producing a stereoscopic image of an invisible radiation scene device. In such a device, two visible images are produced to correspond to two shifted views of an invisible radiation scene, for example an infrared scene. By providing the device with two displaced optical channels, the observer can more easily judge distances from the observer to observed objects.

Conventional stereoscopic infrared imagers provide two optical channels by providing two complete infrared imagers. Such stereoscopic infrared imagers have two complete sets of input optics, scanners, detectors, amplifiers, displays, and output optics. Such duplication results in a device which is large, heavy, expensive to manufacture, and expensive to maintain.

It is an object of the invention to provide a device for producing a stereoscopic image in which the two optical channels share as many components as possible. By sharing components, the device can be made smaller, lighter, and less expensive to manufacture and maintain.

The device according to the invention is characterized by

a first optical channel comprising optics for producing a first invisible image of the scene viewed from a first viewing position;

a second optical channel comprising optics for producing a second invisible radiation image of the scene viewed from a second viewing position spaced from the first viewing position;

a radiation detector for detecting the invisible radiation images;

an input scanning element for alternately scanning the first and second invisible radiation images across the

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detector, each scan having a starting time and a scan rate;

a light source;

a control circuit for the light source to produce visible light having an intensity proportional to the
5 intensity of the infrared radiation incident on the detector;

a third optical channel comprising optics for producing a first visible image of the light source in a first field of view at a third viewing position;

10 a fourth optical channel comprising optics for producing a second visible image of the light source in a second field of view at a fourth viewing position spaced from the third viewing position;

a display scanning element for alternately
15 scanning the first visible image across the first field of view and the second visible image across the second field of view, each scan having a starting time and a scan rate; and

means for synchronizing the starting time and
20 scan rate of the visible scanning means with the starting time and scan rate of the invisible radiation scanning means

As mentioned above, the invisible radiation is preferably infrared radiation. However, in principal the stereoscopic imager according to the invention can be
25 used to generate visible images corresponding to images in any other radiation band.

The device according to the invention may be further characterized in that the first optical channel comprises:

30 a first stationary input mirror arranged to receive infrared radiation from the scene and to reflect said infrared radiation; and

First lens means arranged to receive scene radiation reflected from the first stationary input mirror,
35 said first lens means producing an infrared image of the scene in a focal plane.

and in that the second optical channel comprises:

a second stationary input mirror arranged to receive infrared radiation from the scene and to reflect said infrared radiation, said second stationary input mirror being spaced from the first stationary input mirror; and

5 second lens means arranged to receive scene radiation reflected from the second stationary input mirror, said second lens means producing an infrared image of the scene in a focal plane.

Preferably, the device according to the
10 invention is further characterized in that

both lens means comprise a single input lens; and the input scanning element comprises a rotating input mirror arranged to receive infrared radiation from the scene after reflection from the first and second stationary
15 input mirrors, and further arranged to alternately reflect radiation from the first and second stationary input mirrors to the input lens.

The rotating input mirror may be a mirror prism with three reflective sides.

20 The device of the present invention may be further characterized in that

both display lens means comprise a single objective lens;

The display scanning element comprises a rotating
25 display mirror arranged to receive light from the light source by way of the objective lens, said rotating display mirror being arranged to alternately reflect said light to the first and second stationary display mirrors.

Preferably, both display lens means comprise a
30 single objective lens and the display scanning element comprises a rotating display mirror arranged to receive light from the light source by way of the objective lens. Said rotating display mirror is also arranged to alternately reflect said light to the first and second stationary
35 display mirrors.

The rotating display mirror may be a mirror prism with three reflective sides.

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In one aspect of the invention, the synchronization means comprises a gear train forming a mechanical linkage between the input scanning element and the display scanning mirror.

5 Preferably, the infrared radiation detector comprises a linear array of infrared radiation detectors arranged in the focal plane of the input lens.

The light source comprises preferably a linear array of light emitting diodes, each light emitting diode
10 in the diode array corresponding to one infrared detector in the detector array.

According to a further characterizing feature, each infrared detector produces an output electrical signal having a magnitude proportional to the
15 intensity of the infrared radiation incident thereon, each light source produces visible light having an intensity proportional to the magnitude of an input electrical signal applied thereto, and the control circuit for the light source comprises an array of electric amplifiers
20 having inputs connected to the outputs of the infrared detectors and having outputs connected to the inputs of the light sources.

The third and fourth optical channel may further include first and second eyepiece lenses arranged to
25 receive light reflected from the first and second stationary display mirrors, respectively.

The invention will now be described with reference to the drawing, wherein

Figure 1 is a partly schematic, partly top plan
30 view of an infrared scanning and imaging portion of a stereoscopic infrared imager according to the invention,

Fig. 2 is a partly schematic, partly top plan view of a visible scanning and imaging portion of a stereoscopic infrared imager according to the invention,

35 Figure 3 is a graph of the azimuthal position χ of the scene being scanned across the detector as a function of the angular rotation φ of the infrared and visible scanning mirrors,

Figure 4 is a top plan view of a portion of a stereoscopic infrared imager according to the invention for synchronizing the rotations of the infrared and visible scanning mirrors,

5 Figure 5 is a schematic diagram of a lens system for producing a visible image of the light source in the infrared imager according to the invention.

Figure 1 shows a portion of a stereoscopic infrared imager according to the invention for scanning an
10 infrared radiation image of the scene across a detector array. The infrared radiation scene is represented in Figure 1 by the numerals 10, 10', 12, 12', 14 and 14', which denote successive positions in the scene viewed from right to left. Light rays 16 from the scene are incident on
15 stationary input mirrors 18 and 20 which are spaced apart from one another by a distance, d . In conjunction with input lens 22 the stationary input mirrors 18 and 20 produce first and second infrared radiation images of the scene viewed from spaced apart positions.

20 Thus, the infrared radiation image of the scene viewed from stationary input mirror 18 finds the scene position 12' in the center of the image. In contrast, the infrared radiation image of the scene viewed from the stationary input mirror 20 is shifted slightly to the right
25 and finds the scene position 12 in the centre of the image. The larger the spacing, d , between the mirrors 18 and 20, the larger will be the relative shifting between the images and the larger will be the stereoscopic effect.

In order to sense the infrared images of the
30 scene, a radiation detector 24 is provided at the location of the infrared images. In the device shown in Figure 1, the detector 24 is an array made up of a number of infrared detector elements extending in a direction perpendicular to the plane of the drawing. The infrared detector elements
35 may be, for example, cryogenically-cooled quantum detectors or pyroelectric point detectors.

As described thusfar, the stereoscopic imager

forms two shifted infrared images of the scene, but has only one detector array. In order to detect both images with a single detector array, a rotating input mirror 26 is provided. Rotating input mirror 26 alternately scans the first and second infrared radiation images across the detector array 24.

As shown in Figure 1, as the rotating input mirror 26 rotates clockwise, the infrared scene is scanned from right to left across the detector array 24 via stationary input mirror 18. As the rotating input mirror 26 continues to rotate, the inside of the imager (preferably blackened) is scanned across the array until the rotating input mirror 26 reaches the position shown in dotted lines in Figure 1. At this point, the infrared radiation scene is scanned from right to left across the detector array via stationary input mirror 20.

Figure 2 shows the portion of the stereoscopic imager for generating the stereoscopic visible images. A light source 28 may be, for example, a linear array of light emitting diodes. The array extends in a direction perpendicular to the plane of the drawing.

Amplifier 10 is an array of amplifiers provided for driving the light source array 28 to produce visible light. Each infrared detector in detector array 24 produces an output electrical signal having a magnitude proportional to the intensity of the infrared radiation incident thereon. The output electrical signals from the infrared detectors are input to associated amplifiers in array 10. The output of each amplifier in array 30 drives an associated light source in light source array 28 so that each light source produces visible light having an intensity proportional to the intensity of the infrared radiation incident on the corresponding infrared detector in the detector array 24.

First and second visible images of the light source array 28 are produced in first and second spaced-apart fields of view by an objective lens 32 and by first

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and second stationary display mirrors 34 and 36. The stationary display mirrors 34 and 36 are separated by a distance, d' , which may be the average distance between the two eyes of a human observer.

5 While the distance, d , between stationary input mirrors 18 and 20 may be equal to the distance, d' , between the stationary display mirrors 34 and 36, preferably the distance d exceeds the distance d' . Providing d greater than d' exaggerates the perspective viewed
10 by the observer, thereby compensating for the observer's difficulty in interpreting the visible analog to the infrared scene.

 In order to reconstruct two different complete visible images corresponding to the infrared scene from
15 only a single light source array, a rotating display mirror 38 is provided. As the rotating display mirror 38 rotates counterclockwise, an image of the light source array 28 is scanned from right to left across the left eye
40 of an observer. After further rotation of the rotating display mirror 38, the inside of the imager (preferably
20 blackened) is imaged on the observer's eyes. After further rotation of the rotating display mirror 38, an image of the light source array 28 is scanned from right to left across the right eye 42 of the observer.

25 In order to create the sensation that the observer is viewing two complete and continuous two-dimensional visible images, the mirrors 26 and 38 must be rotated at a sufficiently high angular velocity. For the case where three-sided scanning mirrors are used, the
30 mirrors may be rotated, for example, at 300 revolutions per minute. This will result in a scan rate of 15 frames per second from each optical channel (30 frames per second total).

 In the stereoscopic imager described thusfar,
35 the infrared images were shifted relative to each other by using stationary input mirrors 18 and 20, and the visible images were shifted relative to each other by using

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stationary display mirrors 34 and 36. Scanning was performed by scanning mirrors 26 and 38. While the use of mirrors for shifting and for scanning is preferred, other optical elements could be used in place of these mirrors, For example, the mirrors could be replaced with refracting prisms. Anychromatic aberration produced by the refracting prisms could be corrected with suitable correcting elements.

Moreover, as described thusfar, rotating input mirror 26 and rotating display mirror 38 each have three reflective sides. Alternatively, other rotating mirror arrangements may be used. For example, by providing a scanning prism having a larger number of faces, it is possible to decrease the angular velocity of the mirror for the same frame rate, or conversely it is possible to increase the frame rate and maintain the same angular velocity of the mirror.

Figure 3 graphically shows the scanning of the infrared scene by a stereoscopic imager having a 30° field of view. When the angular position φ of the rotating input mirror 26 is at zero degrees (the solid-line position shown in Figure 1), an image of the scene position 10' is produced on the detector array 24 via input mirror 18. As the rotating input mirror 26 rotates clockwise, the infrared image of the scene is scanned across the detector array 24 until an image of the scene position 14' is produced on the detector array 24 when the angular position of the rotating input mirror 26 is 15° . Thus, while the rotating input mirror 26 rotates 15° , the field of view of the stereoscopic imager is 30° . The field of view may be either higher or lower than 30° , as may be required.

While the rotating input mirror 26 rotates from 15° to 45° , an image of the blackened interior (not shown) of the imager is produced on the detector array 24. Thereafter, at 45° an image of the scene position 10 is produced on the detector array 24 via the stationary input mirror 20. From 45° to 60° , the image of the scene is

scanned across the detector array 24 until an image of the scene position 14 is produced on the detector array 24. Thereafter, an image of the darkened interior of the imager is produced on the detector array from 60° to 120° .
5 Since the rotating input mirror 26 has three reflective surfaces, this cycle is repeated three times for each rotation of the rotating input mirror 26.

In order to assure that the visible images reconstructed by the components shown in Figure 2
10 correspond to the infrared images of the scene, the starting time and scan rate of the rotating display mirror 38 must be synchronized with the starting time and the scan rate of the rotating input mirror 26. One such arrangement for synchronizing the rotating input and
15 display mirrors is shown in Figure 4. The rotating input mirror 26 rotates on a shaft 44 while the rotating display mirror 38 rotates on a shaft 46. The rotating input mirror 26 is arranged in plane below the plane of the rotating display mirror 38 so that the formation of the infrared
20 images and the formation of the visible images will not interfere with each other.

As noted above, the starting time and scan rate (rate of rotation) of the rotating input mirror 26 and the rotating display mirror 38 must be synchronized while ro-
25 tating the input and display mirrors in opposite directions. This is accomplished by providing a gear train in a plane between the planes of the rotating input mirror 26 and the rotating display mirror 38. The gear train includes gears 48 and 50. The gears have the same
30 number of teeth per revolution so that the rotating mirrors will rotate at the same angular velocity. Moreover, the rotating mirrors are aligned so that the visible and infrared scans start at the same time.

An electric motor may be connected to either
35 shaft 44 or shaft 46 in order to rotate both mirrors 26 and 38.

The starting time and scan rate of the rotating

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input mirror 26 and rotating display mirror 38 can,
alternatively, be synchronized in other ways. For example,
a single scanning mirror could be used for scanning both
the infrared scene and the light source. The lower portion
5 of the rotating mirror could be used for scanning the
infrared scene, and the upper portion of the rotating mirror
could be used for scanning the light source. A reversing
lens could be placed between the input lens 22 and the
detector array 24 (Figure 1) to compensate for the
10 rotation of both the rotating input mirror and the rotating
display mirror in the same direction.

Figure 5 shows a lens system which can be used
for producing a visible image of the light source array 28.
Light from the light source array 28 is focused by the
15 objective lens 32. After reflection from rotating display
mirror 38, a field lens 52 is provided to locate the exit
pupil 56 at the expected location of the observer's eye.
Finally, the eyepiece lens 54 is provided to collimate the
image for the eyes.

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CLAIMS

1. A device for producing a stereoscopic visible image of an invisible radiation scene, characterized by:

a first optical channel comprising optics for producing a first invisible image of the scene viewed from
5 a first viewing position;

a second optical channel comprising optics for producing a second invisible radiation image of the scene viewed from a second viewing position spaced from the first viewing position;

10 a radiation detector for detecting the invisible radiation images;

an input scanning element for alternately scanning the first and second invisible radiation images across the detector, each scan having a starting time
15 and a scan rate;

a light source;

a control circuit for the light source to produce visible light having an intensity proportional to the intensity of the infrared radiation incident on the
20 detector;

a third optical channel comprising optics for producing a first visible image of the light source in a first field of view at a third viewing position;

25 a fourth optical channel comprising optics for producing a second visible image of the light source in a second field of view at a fourth viewing position spaced from the third viewing position;

30 a display scanning element for alternately scanning the first visible image across the first field of view and the second visible image across the second field of view, each scan having a starting time and a scan rate; and

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means for synchronizing the starting time and scan rate of the visible scanning means with the starting time and scan rate of the invisible radiation scanning means.

5 2. A device as claimed in Claim 1, characterized in that the invisible radiation is infrared radiation.

3. A device as claimed in Claims 1 or 2, characterized in that the first optical channel comprises;
a first stationary input mirror arranged to
10 receive infrared radiation from the scene and to reflect said infrared radiation; and

first lens means arranged to receive scene radiation reflected from the first stationary input mirror, said first lens means producing an infrared image of the
15 scene in a focal plane.

and in that the second optical channel comprises;
a second stationary input mirror arranged to receive infrared radiation from the scene and to reflect said infrared radiation, said second stationary input
20 mirror being spaced from the first stationary input mirror; and

second lens means arranged to receive scene radiation reflected from the second stationary input mirror, said second lens means producing an infrared image of the
25 scene in a focal plane.

4. A device as claimed in Claim 3, characterized in that:

both lens means comprise a single input lens;
and

30 the input scanning element comprises a rotating input mirror arranged to receive infrared radiation from the scene after reflection from the first and second stationary input mirrors, and further arranged to alternately reflect radiation from the first and second
35 stationary input mirrors to the input lens.

5. A device as claimed in Claim 4, characterized in that the rotating input mirror comprises a mirror prism with three reflective sides.

6. A device as claimed in any one of Claims 1 - 5 characterized in that the third optical channel comprises:

first display lens means for focusing light from the light source; and

a first stationary display mirror arranged to receive light from the light source after it has passed through the first display lens means, and

in that the fourth optical channel comprises:

second display lens means for focusing light from the light source; and

a second stationary display mirror arranged to receive light from the light source after it has passed through the second display lens means, said second stationary display mirror being spaced from the first stationary display mirror.

7. A device as claimed in Claim 6, characterized in that:

both display lens means comprise a single objective lens;

the display scanning element comprises a rotating display mirror arranged to receive light from the light source by way of the objective lens, said rotating display mirror being arranged to alternately reflect said light to the first and second stationary display mirrors.

8. A device as claimed in Claim 7, characterized in that the rotating display mirror comprises a mirror prism with three reflective sides.

9. A device as claimed in any one of Claims 1 - 8, characterized in that the synchronization means comprises a gear train forming a mechanical linkage between the input scanning element and the display scanning element.

10. A device as claimed in any one of Claims 1 - 9 characterized in that the infrared radiation detector comprises a linear array of infrared radiation detectors arranged in the focal plane of the input lens.

11. A device as claimed in Claim 10,
characterized in that the light source comprises a linear
array of light emitting diodes, each light emitting
diode in the diode array corresponding to one infrared
5 detector in the detector array.

12. A device as claimed in Claim 11, characterized in
that:

each infrared detector produces an output
electrical signal having a magnitude proportional to the
10 intensity of the infrared radiation incident thereon;

each light source has an input and produces
visible light having an intensity proportional to the
magnitude of an input electrical signal applied thereto;
and

15 the control circuit for the light source comprises
an array of electric amplifiers, each amplifier having an
input connected to the output of an associated infrared
detector and having an output connected to the input of an
associated light source.

20 13. A device as claimed in any one of Claims 6 - 12
characterized in that :

the third optical channel further comprises a first
eyepiece lens arranged to receive light source light reflec-
ted from the first stationary display mirror; and

25 the fourth optical channel further comprises a
second eyepiece lens arranged to receive light source light
reflected from the second stationary display mirror.

